SPECTRAL MODELS FOR ESTIMATION OF CHLOROPHYLL CONTENT, NITROGEN, MOISTURE STRESS AND GROWTH OF WHEAT CROP

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ABSTRACT

Field experiments were conducted during 2009-10 and 2010-11 at research farm of the department of Farm Machinery and Power Engineering, Punjab Agricultural university, Ludhiana. Three wheat cultivars : PBW 343, PBW 55, DBW 17 were sown on 12th November and 20th November in the year 2009-10 and 2010 -11 respectively with five nitrogen levels viz., no nitrogen (N1), 75 kg/ha (N2), 125 kg/ha (N3) recommended dose, 175 kg/ha (N4) and 225 kg/ha (N5). Leaf Area Index (LAI), Dry Matter (DM) at an thesis, Plant Height and Chlorophyll Concentration Index (CCI) were recorded in all the treatments. Chlorophyll and nitrogen contents of wheat leaves were estimated at different growth stages. Multiband spectral reflectance was measured using hand-held spectroradiometer. Spectral indices such as Normalized difference Vegetation Index (NDVI), Ratio Vegetation Index (RVI), Moisture Stress Index (MSI), Green Index (GI), Leaf Chlorophyll Index (LCI), Plant Senescence Reflectance Index (PSRI), were computed using the multiband spectral data. Values of all the spectral indices were maximum with maximum dose of nitrogen (225 kg/ha) up to heading stage. The spectral indices recorded during mature tillering stage were better correlated with crop parameters. All the spectral indices recorded at tillering stage have good correlation with all the crop parameters having 'r^2' values varied between 0.68(GI and Chlorophyll), 0.73(RVI and Chlorophyll), 0.74 (NDVI and Nitrogen* LAI), 0.70(PSRI and Nitrogen*LAI), 0.76 (LCI and

nitrogen*LAI), 0.73(MSI and LAI), 0.73(RVI and LAI) and 0.74(MSI and Plant Height), 0.83(LCI and Plant Height), 0.76 (NDVI and Plant Height).
Keywords: Spectral indices, LAI, Plant Chlorophyll, Plant Nitrogen

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INTRODUCTION

The remote sensing technique is being used extensively in natural and physical resource inventoring, mapping and monitoring. The major applications in the field of agrometeorology are for the management of land and water resource, crop production forecasting and to disaster assessment such as flood, drought, epidemics etc. which seriously affect the agriculture. Effective crop management and yield prediction over a large area would be possible by remote sensing techniques, through operational models on crop growth and development. The operational models are based on the fact that each crop has a unique spectral signature. Spectral response of a crop canopy is influenced by leaf area index, per cent ground cover, growth stages, difference in cultural practices, stress conditions, attack of pest and diseases, canopy architecture etc. (Sompal, 1999). Spectral reflectance properties in different wavelength bands are utilized in crop identification, yield forecasting and crop condition assessment (Bauer, 1985). Das and Kalra (1990) and Das (1992) reviewed researches on the use of spectral measurements in various aspects of crop. Though Punjab is a one of the smallest state with a total land area of only 0.33% of the world and 1.6% of the country yet it contributes 2% of the wheat in world production vis-à-vis 55% wheat in the country. Punjab has topped the country in contributing food grain to the Central pool. Of the three main crops of Northern region paddy, wheat and sugar that go to the Central pool from states, Punjab has topped in wheat and paddy contribution. As on June, 1, 2011, the total food grain stock, 61.83 lakhs metric tones share is of rice, whereas the wheat stock is about 17.82 lakhs MT.

Keeping these facts in view, an attempt has been made to study the feasibility of wheat crop through remote sensing technique to develop the spectral models to delineate the lengthy laboratory testing procedures.

MATERIAL AND METHODS

Field Experiment

The field experiment was conducted during Rabi season of during 2009-10 and 2010-11at the research farm of the Department of Farm Machinery and Power Engineering, Punjab Agricultural University, Ludhiana. Three wheat genotypes PBW 343(V1), PBW 550(V2), DBW 17 (V3) were sown on 12th November and 20th November in the year 2009-10 and 2010 -11 respectively with five nitrogen levels: No nitrogen (N1), 75 kg/ha (N2), 125 kg/ha (N3) recommended dose, 175 kg/ha (N4) and 225 kg/ha kg N/ha (N5). The experiment was laid out in a split plot design with three replications (Fig1). All other agronomic practices were followed as per package of practices recommended for wheat crop by the University. The leaf area was measured with leaf area meter (Licor-3100) at different plant growth stages starting CRI onwards to physiological maturity. Photosynthetic pigments were estimated according to the method of Hiscox and lsraelstam (1979) using dimethyl sulphoxide (DMSO). Calculation of chlorophyll a and b were made according to the equation developed by Anderson and Boardman (1964). The wax content of wheat leaves was estimated as per the procedure adopted by Silva Fernandes *et al.* (1964). Chlorophyll Concentration Index (CCI) was taken by using Apogee's CCM-200. Other agronomic parameters such as plant height, number of tillers were taken manually. The whole two years data was averaged to do further analysis.

R1, 16 m				R2, 16 m				R3, 16 m		
N1	N5	N3		N5	N3	N2		N1	N2	N3
N3	N2	N1		N4	N2	N4		N2	N1	N4
N2	N4	N2		N1	N5	N1		N5	N3	N2
N4	N1	N4		N2	N4	N3		N3	N4	N5
N5	N3	N5		N3	N1	N5		N4	N5	N1
NON EXPERIMENTAL										

V1 V2 V3 V1 V2 V3 V1
V2 V3

Treatment details:

Variety	Nitrogen Treatments
V1= PBW 343	N1- Controlled
V2= PBW 550	N2-75 kg N/ha
V3= DBW 17	N3-125 kg N/ha
	N4-175 kg N/ha
	N5-225 kg N/ha

Fig. 1 layout plan of the experiment

Collection of spectral Data

Collection of spectral reflectance for wheat crop for detection of disease infestation was collected using a 512-channel spectro radiometer (Fieldspec®Pro 2000) with a range of 325 to 2500 nm. The instrument acquired hyper spectral data at the spectral resolution of 3 nm. But by sampling, the instrument delivers data with 1 nm interval. The target reflectance is the ratio of energy reflected off the target (e.g. crop) to energy incident on the target (measured using $BaSO_4$ white reference). Reflectance measurements were made about one meter above the crop canopy with the sensor facing the crop and oriented normal to the plant using 25° field of view (FOV). The data was taken on cloud free days at around solar noontime (ignoring sharp 12:00 in the noon time). The following spectral indices given in Table.1 computed using the spectral reflectance data.

Table 1. Narrowband indices computed for the study

Vegetation index (VIs)	Abbre viation	Equations	Properties	References
Normalized difference Vegetation index	NDVI	(R 927- R 687) / (R 927 + R 687)	Green Biomass	Thenkabail et al (2000)
Ratio vegetation index	RVI	R927/ R687	Light Use Efficiency	Thenkabail et al (2000)
Moisture Stress Index	MSI	R 1662/ R927	Water content	Thenkabail et al (2000)
Green Index	GI	R554/R677	Green biomass	Zarco-Tejada et al (1999)
Leaf Chlorophyll Index	LCI	(R850-R710)/(850+680)	Chlorophyll presence	Thenkabail et al (2000)
Plant Senescence Reflectance Index	PSRI	R(680-500)/750	Carotenoid pigments	Sims and Gamon (2002)

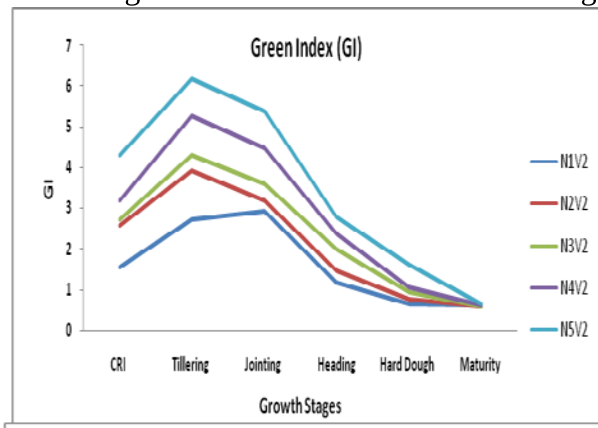
R^{abc} refer to the reflectance at (abc) wavelength

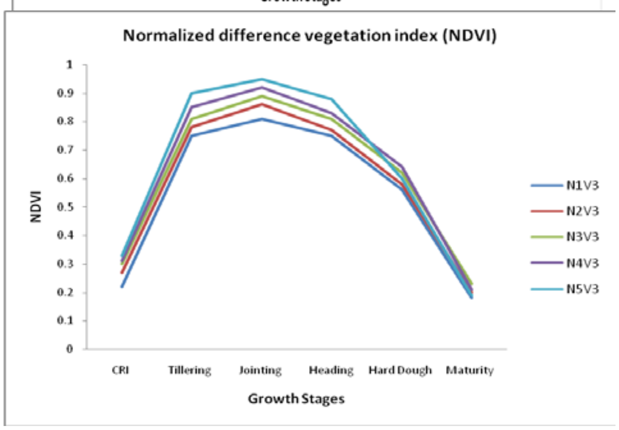
Correlation analysis

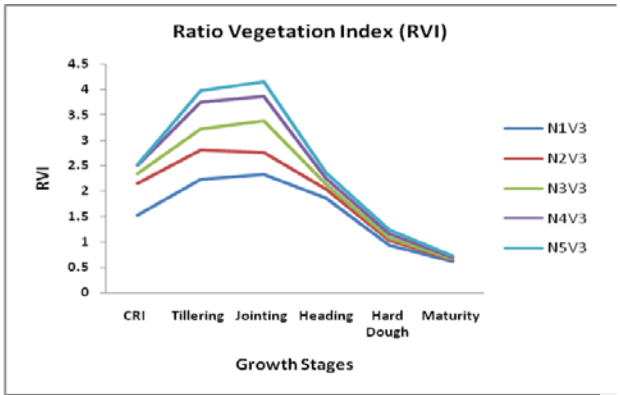
Correlation analysis was carried out between spectral indices and crop parameters recorded at different growth stages. Regression analysis was carried out between significant spectral indices, based on the value of correlation coefficient r^2, and crop parameters. Multiple regression equations were developed using step-wise regression technique by using Unscrambler statistical software (version 10)

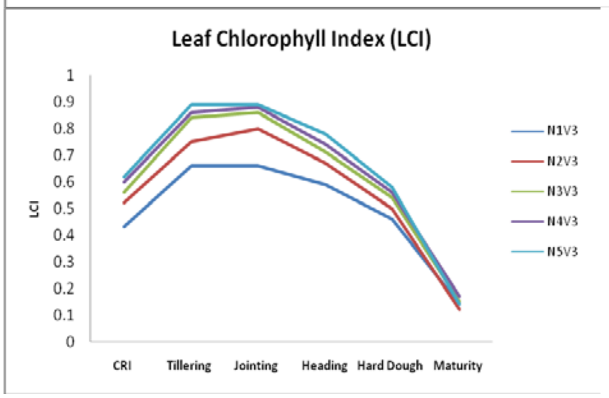
RESULTS & DISCUSSIONS

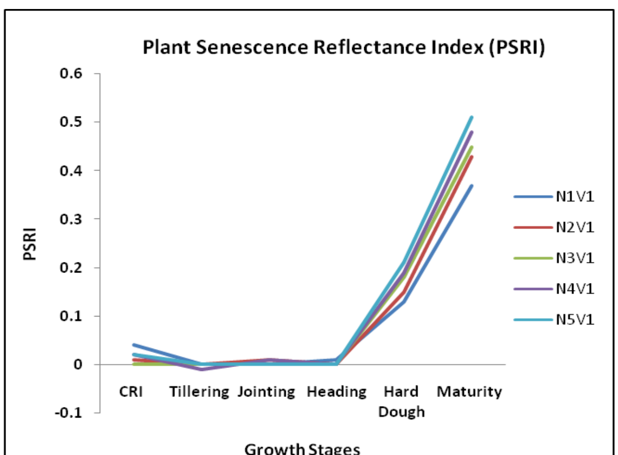
The temporal variation in different vegetation indices of different wheat genotypes at different nitrogen levels is depicted in Fig.2. The indices derived in V-NIR region like NDVI, GI, RVI and LCI increased in the early vegetative period up to full vegetative phases (Tillering/jointing). It reached at peak around jointing stage nearly 75 DAS then it declined towards maturity of crop in all the treatments. The PSRI and MSI is minimum in-between tillering to heading stage due to full supply of nitrogen and water to the plant and after this it increased rapidly due to crop maturity and beginning of plant senescence. The most visible symptom of plant senescence is leaf yellowing, due to decline in total protein, lipids and RNA levels. Other reasons of plant senescence are Chloroplast and other organelles breakdown. Plant senescence affects the reflectance properties of plants. This is the reason why vegetation indices NDVI, GI, RVI and LCI have decreasing and MSI and PSRI have increasing trends after heading stage.






Ratio Vegetation Index (RVI)
RVI
4.5
4
3.5
3
2.5
2
1.5
1
0.5
0
CRI
Tillering
Jointing
Heading
Hard Dough
Maturity
Growth Stages
N1V3
N2V3
N3V3
N4V3
N5V3


Leaf Chlorophyll Index (LCI)
LCI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CRI
Tillering
Jointing
Heading
Hard Dough
Maturity
N1V3
N2V3
N3V3
N4V3
N5V3


Plant Senescence Reflectance Index (PSRI)
PSRI
0.6
0.5
0.4
0.3
0.2
0.1
0
-0.1
CRI
Tillering
Jointing
Heading
Hard Dough
Maturity
Growth Stages
N1V1
N2V1
N3V1
N4V1
N5V1

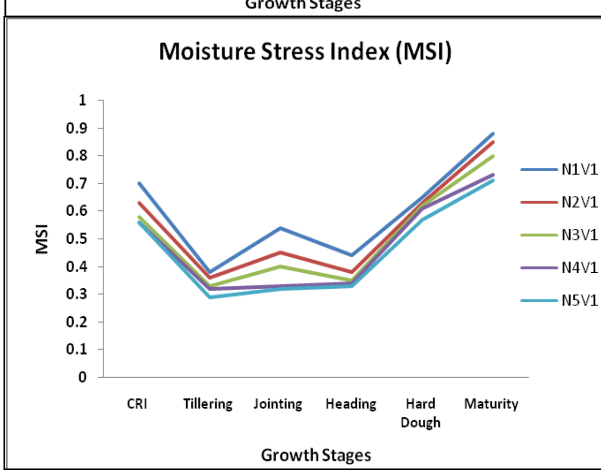
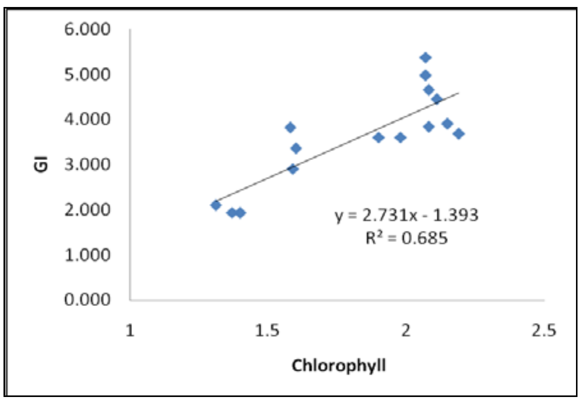
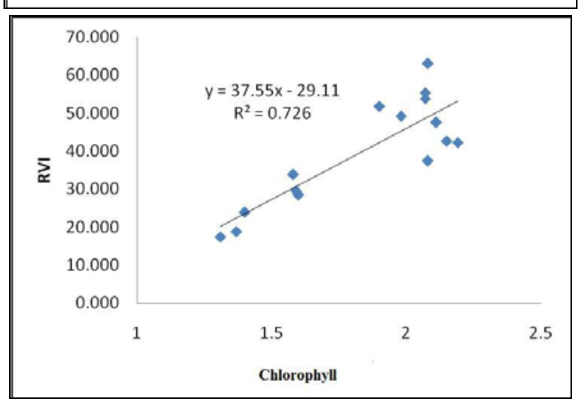

Moisture Stress Index (MSI)
MSI
1
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
CRI
Tillering
Jointing
Heading
Hard Dough
Maturity
Growth Stages
N1V1
N2V1
N3V1
N4V1
N5V1

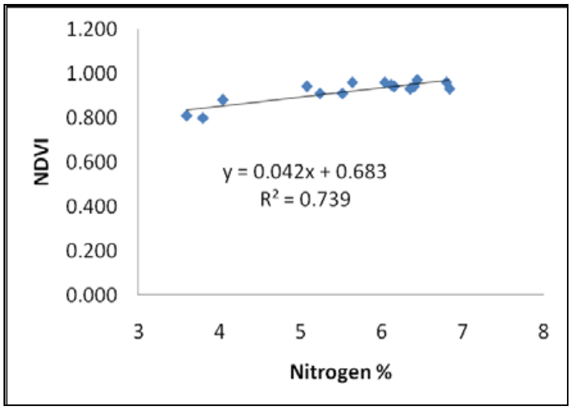
Fig.2: different vegetation indices of different wheat genotypes at different plant growth stages and different nitrogen levels

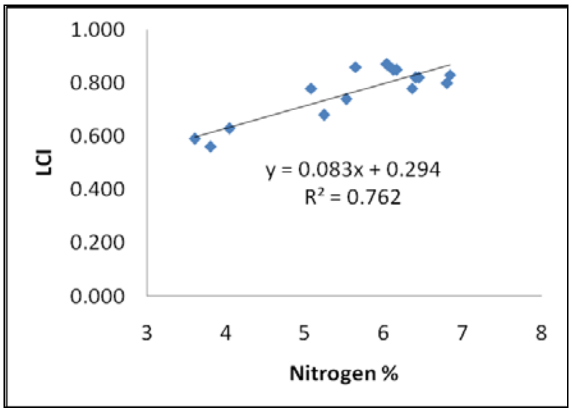
Relationship between Spectral indices with different crop parameters

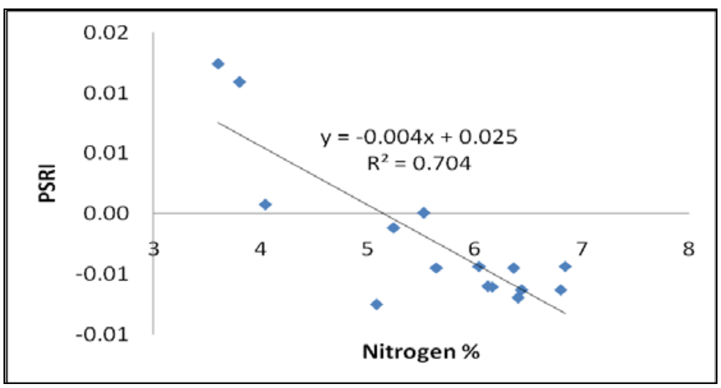
The correlation coefficient between spectral indices and crop parameters at different plant growth stages are presented in Fig. 3. Spectral indices recorded at mature tillering stage were better correlated with crop parameters as compared to other phenophases (Fig.3). the same results were presented by Mahey et al. (1991) that correlation between different agronomic parameters and vegetation indices was maximum at 75-105 days after sowing.This might be due to more groud coverage by the crop at this stage as compared to other growth stages. In the early stages the visibility of soil may be the reason of the low correlation. So taking this view in consideration correlation model has been developed for the mature tillering stage. All the spectral indices recorded at tillering stage have good correlation with all the crop parameters having 'r^2' values varied between 0.68(GI and Chlorophyll), 0.73(RVI and Chlorophyll), 0.74 (NDVI and Nitrogen* LAI), 0.70(PSRI and Nitrogen*LAI), 0.76 (LCI and nitrogen*LAI), 0.73(MSI and LAI), 0.73(RVI and LAI) and 0.74(MSI and Plant Height), 0.83(LCI and Plant Height), 0.76 (NDVI and Plant Height).

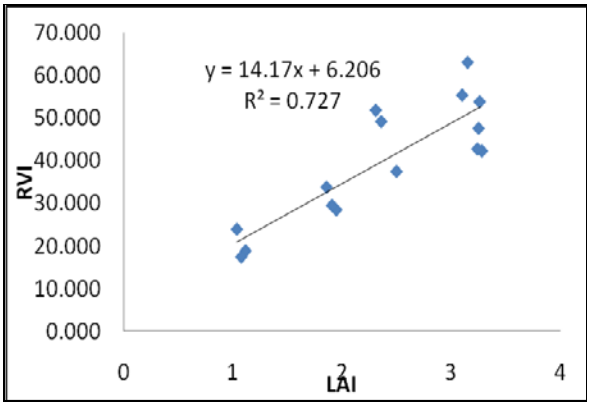


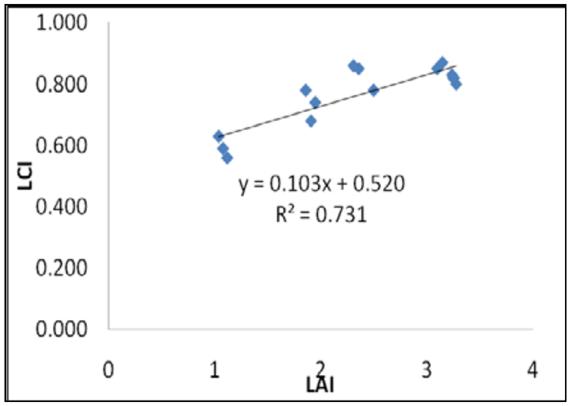


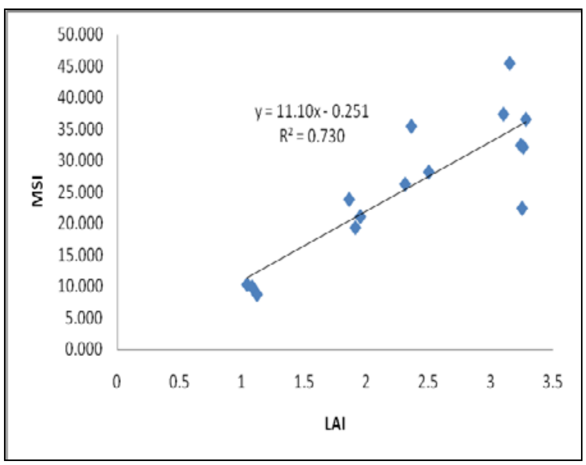

1.200
1.000
0.800
0.600
0.400
0.200
0.000
NDVI
y = 0.042x + 0.683
R² = 0.739
3
4
5
6
7
8
Nitrogen %

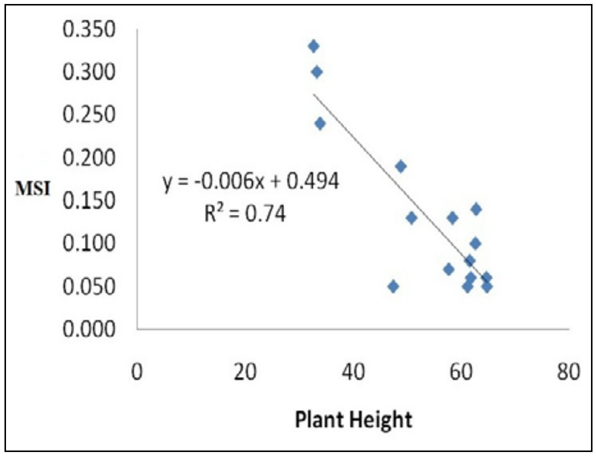

1.000
0.800
0.600
0.400
0.200
0.000
LCI
y = 0.083x + 0.294
R² = 0.762
3
4
5
6
7
8
Nitrogen %

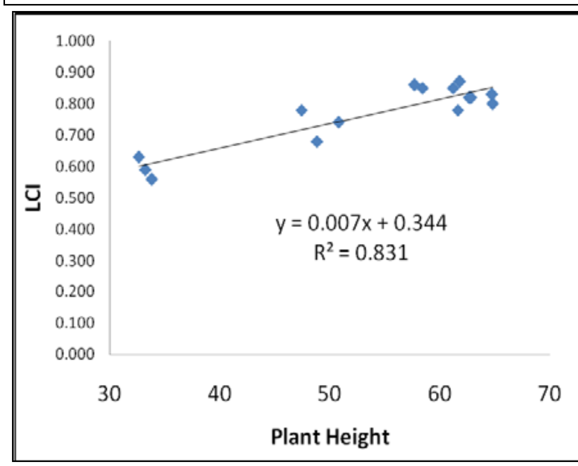

0.02
0.01
0.01
0.00
-0.01
-0.01
PSRI
y = -0.004x + 0.025
R² = 0.704
3
4
5
6
7
8
Nitrogen %


70.000
60.000
50.000
40.000
30.000
20.000
10.000
0.000
RVI
y = 14.17x + 6.206
R² = 0.727
0
1
2
3
4
LAI


1.000
0.800
0.600
0.400
0.200
0.000
LCI
y = 0.103x + 0.520
R² = 0.731
0
1
2
3
4
LAI


50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0.000
MSI
y = 11.10x - 0.251
R² = 0.730
0
0.5
1
1.5
2
2.5
3
3.5
LAI





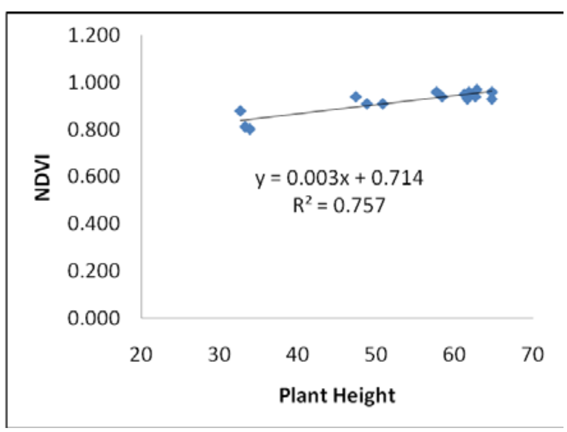


Fig 3. Coefficient of Correlation between Crop Parameters and Spectral Indices

CONCLUSIONS

The best correlation between different agronomic parameters and vegetation indices is observed at mature tillering stage. Correlation derived between different agronomic parameters and vegetation indices is good. NDVI, LCI, GI, RVI indices have increasing trend up to jointing stage and declining trend after jointing stage due to crop maturity and MSI and PSRI vice versa.

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